Forest Health Protection

Report 00-7 **May 2000**

ANALYSIS OF DOUGLAS-FIR BEETLE POPULATION DYNAMICS FROM AERIAL SURVEY DATA USING GROUP SIZE ANALYSIS

Carol Randall, Entomologist
Forest Health Protection, Coeur d'Alene, Idaho

INTRODUCTION

Douglas-fir beetles (*Dendroctonus pseudotsugae*) (DFB) kill discrete groups of Douglas-fir (*Pseudotsuga menziesii*)(DF). As populations of DFB increase, so do numbers of trees killed within an individual group and numbers of groups killed. As populations subside, so do numbers of groups killed and numbers of trees killed within a group (Furniss et al. 1979).

Each year Forest Health Protection staff conducts an aerial detection survey (ADS) for bark beetles and other forest pests. Areas of tree damage/mortality and causal agents are sketched on a map and the maps are digitized. The resulting sketch maps and geographic information system (GIS) digitized maps show where forest pests were active and give managers an approximation of the amount of damage they caused. Aerial surveyors map only current fading trees, ignoring older dead trees. Because these surveys are conducted annually and only capture new faders, results may be compared from year to year to determine trend. Since bark-beetle-killed trees fade approximately 1 year after trees are attacked and killed, ADS results reflect previous year's beetle mortality.

Typically, ADS results for bark beetles are reported in terms of acres infested and numbers of faded trees mapped. While this method enables comparisons of beetle mortality from year to year, it does not maximize use of data by describing spatial distribution of beetles throughout the reporting area. For DFB, which tends to kill trees in groups, reporting aerial survey results in terms of acres infested and numbers of fading trees usually results in an average of 2 to 3 faded trees per acre. This tends to underestimate patchiness of DFB mortality. Spatial distribution of DFB mortality is better conveyed by also reporting numbers and sizes (numbers of faded trees) of groups.

Methods

Aerial detection survey maps for three north Idaho National Forests (NFs) (Idaho Panhandle National Forests (IPNFs), Clearwater National Forest (CNF), and Nez Perce National Forest (NPNF) including private lands within the NF boundaries) were collected for the past 5 years. The total number of groups with tree mortality attributed to DFB (DFB groups) were counted for each Ranger District by the following size classes: 1-19 faded trees, 20-99 faded trees, 100-249 faded trees, 250-499 faded trees, 500-999 faded trees, 1,000-4,999 faded trees, and 5,000+ faded trees. For

this analysis, groups were counted from hard copy maps. With digitized maps, a GIS, such as Arcview, can be used to automate this process.

Size classes were determined based upon a close examination of maps and frequency and general area (acres) associated with different numbers of faded trees noted. Groups with 1-19 faded trees were considered small, generally had a point or very small polygon associated with them on the aerial detection survey map, and were the most common groups counted in years with little overall beetle activity. Medium-sized groups, 20-99, were generally larger than a point on the map, but still rather small polygons, and were not common in years in which aerial detection surveys did not attribute many faded trees to DFB attack. Larger size classes, 100+ faded trees, had more variability in terms of the number of acres incorporated in the group. These classes were exceedingly rare in years with few faded trees attributed to DFB. In many cases, these size classes represent portions of a landscape with numerous small groups in close proximity. To facilitate mapping, the aerial surveyor would draw a larger polygon and incorporate as many small groups as possible. When looking at the total number of groups, it is important to recognize that a 250-499 faded tree group on the ground, may represent five 50-faded tree groups, or even forty 10-faded tree groups in a fairly localized area.

Group analysis was used in addition to numbers of acres infested and faded trees from aerial survey for a variety of reasons. In the main ADS product produced by Forest Health Protection, acres infested and faded tree numbers are summarized for an entire reporting area. It is difficult to characterize trends in a particular portion of a reporting area with numbers from the larger area. With digitized maps and GIS systems, land managers can determine numbers of acres infested and numbers of faded trees from ADS data for a particular area of concern, but it may be necessary to enlist a GIS specialist to assist with this process as it involves some manipulation of the digitized maps. Group analysis may be done in an area of concern without the assistance of GIS in a short time. For this analysis, acres infested and numbers of faded trees were taken from Forest level summaries, and group assessments alone were conducted for Ranger Districts.

Results

Forest Level Summaries

Aerial Detection survey group analysis and summaries of acres infested and numbers of faded trees for all three north Idaho NFs demonstrate increases in DFB tree mortality in 1997 and 1998 (1998 and 1999 ADS) over 1996 levels (Table 1, Table 2, Figures 1-3). Using group analysis, it became evident that as total numbers of trees killed increased, so did the average size of the mortality group. In typical years, most DFB mortality groups are between 1 and 19 faded trees in size. As beetle populations increased across the landscape, so did the number of larger mortality groups, and the proportion of medium to small mortality groups changed dramatically. In the most heavily impacted areas, there were more medium sized groups than small groups. Aerial Detection Surveys conducted in 1999 were not complete on the NPNF, so reduction in group counts, acres infested, and faded trees in 1999 for this NF does not signal a decrease in beetle activity. Average sizes of groups increased indicating more activity in 1998 than in 1997.

Idaho Panhandle National Forests

During the winter of 1996/1997, ice, heavy snows, and wind storms damaged and brought down large numbers of DF trees. These trees were attacked in 1997, and beetle populations rose dramatically. In the spring of 1998, beetles left the damaged and down trees and attacked standing green trees. Mortality caused by beetle attacks in 1998 became evident in 1999 aerial survey data.

Table 1. Numbers of Douglas-fir-beetle-killed groups of trees by approximate group size (numbers of dead trees) as mapped in aerial detection surveys for the Idaho Panhandle, Clearwater, and Nez Perce National Forests for aerial survey years 1995-1999.

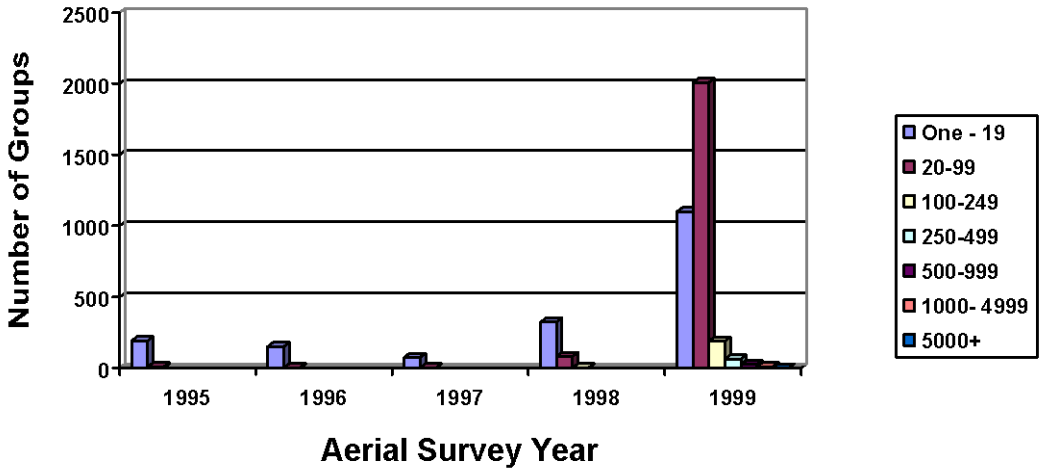
National Forest	Aerial Survey Year	Number of Faded Trees						
		1-19	20-99	100-249	250-499	500-999	1000-4999	5000+
IPNFs	1995	192	10					
	1996	152	3					
	1997	74	2					
	1998	323	82	3				
	1999	1099	2011	190	64	25	10	1
CNF	1995	317	60	3	1			
	1996	216	53					
	1997	147	22					
	1998	939	334	34	10	3		
	1999	865	499	45	6	6		
NPNF	1995	53	21					
	1996	270	106	5	1			
	1997	231	81	1				
	1998	908	594	30	4			
	1999*	728	703	32	5	2		

*Aerial surveys were incomplete for the Red River, Selway, and Moose Creek Ranger Districts of the NPNF.

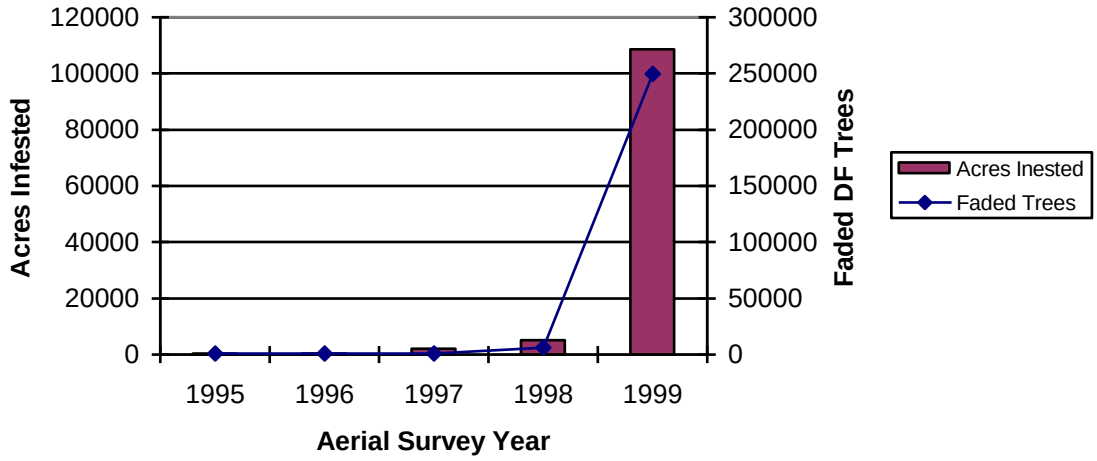
Table 2. Numbers of acres infested and numbers of faded trees determined from ADS for the Idaho Panhandle, Clearwater, and Nez Perce National Forests for aerial survey years 1995-1999.

National Forest	Aerial Survey Year	Acres Infested	Faded Trees
IPNFs	1995	420	856
	1996	330	788
	1997	2,164	807
	1998	5,179	6276
	1999	10,8529	249,598
Clearwater NF	1995	6,350	2,174
	1996	607	2,593
	1997	1,367	2,186
	1998	26,734	25,121
	1999	11,659	34,150
Nez Perce NF	1995	277	962
	1996	1,786	6,626
	1997	1,775	862
	1998	1,5480	35,348
	1999	14,664	42,214

Figure 1. Numbers of Douglas-fir-beetle-killed groups of trees by approximate group size (number of dead trees) as mapped in aerial detection surveys for the Idaho Panhandle National Forests for aerial survey years 1995-1999.



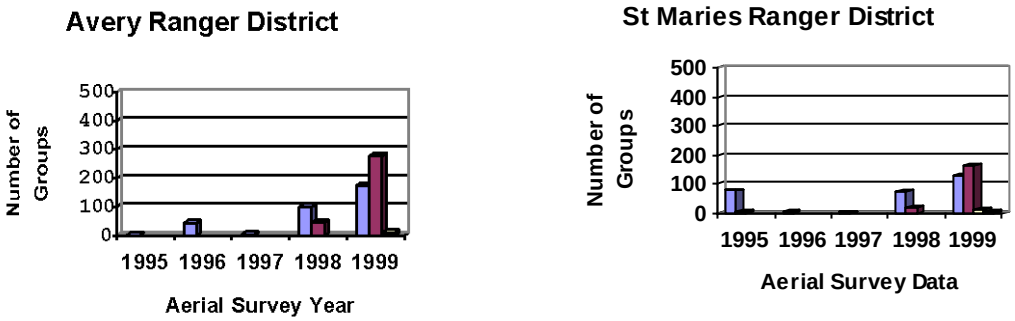
National Forest	Aerial Survey Year	Acres Infested	Faded Trees
IPNFs	1995	420	856
	1996	330	788
	1997	2,164	807
	1998	5,179	6,276
	1999	108,529	249,598



Group assessment at the Ranger District level on the IPNFs shows regional differences in how beetle populations increased. A dramatic increase was noted on all Districts in 1999 aerial surveys, but the scale of increase and extent of beetle mortality in years preceding the 1999 flight differs.

Southern Portion of the Forest: Avery and St Maries

Figure 2. Numbers of Douglas-fir-beetle-killed groups of trees by approximate group size (number of faded trees) as mapped in aerial detection surveys for the Avery and St. Maries Ranger Districts of the IPNFs for aerial survey years 1995-1999.

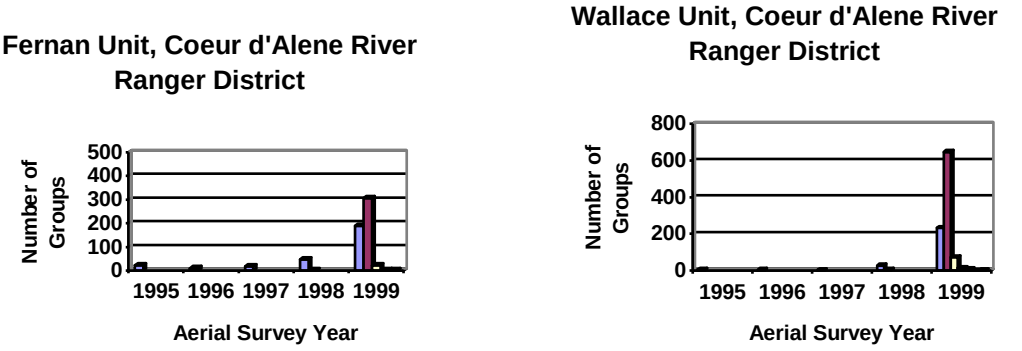


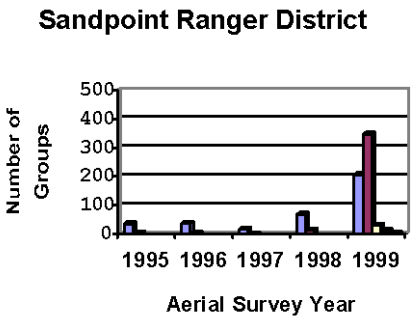
The number of groups of faded trees attributed to DFB attacks began to increase in the southern Districts of the Forest in 1998 ADS (1997 attacks). The number of groups continued to increase in 1999 ADS, as did the number of groups in larger size classes, which were more abundant than small DFB groups on both Districts.

Winter of 1995/1996 was unusually moist in north central Idaho. Additional moisture in the form of snow created scattered downfall, the DFB preferred host. Beetles prefer weakened and down DF trees because they are relatively defenseless and the beetles are able to reproduce in larger numbers. Beetle populations in the spring of 1996 preferentially colonized down material resulting in a slight depression in numbers of DFB killed groups mapped in 1997 (1996 attacks) (Figure 2, Appendix 1). In the spring of 1997, larger numbers of DFB emerged from DF downfall generated in winter 1995/1996. Ice storms did not impact the southern Districts as heavily as other parts of the IPNFs; however, significant snow loads during the winter of 1996/1997 likely resulted in generating considerable Douglas-fir down fall which was colonized by beetles in spring 1997. Beetle populations emerging in spring of 1997, attacked green trees, reflected by the increase in DFB groups in the 1998 ADS, but many beetles colonized downfall which enabled populations to continue to build. The winter of 1997/1998 did not result in the creation of significant DF downfall. Populations of DFB emerging in the spring of 1998 did not have downfall to colonize so large numbers of green trees were attacked and killed.

Central Portion of the Forest: Coeur d'Alene River and Sandpoint

Figure 3. Numbers of Douglas-fir-beetle-killed groups of trees by approximate group size (numbers of faded trees) as mapped in aerial detection surveys for the Coeur d'Alene River Ranger District (Fernan and Wallace Units), and Sandpoint Ranger District of the IPNFs for aerial survey years 1995-1999.

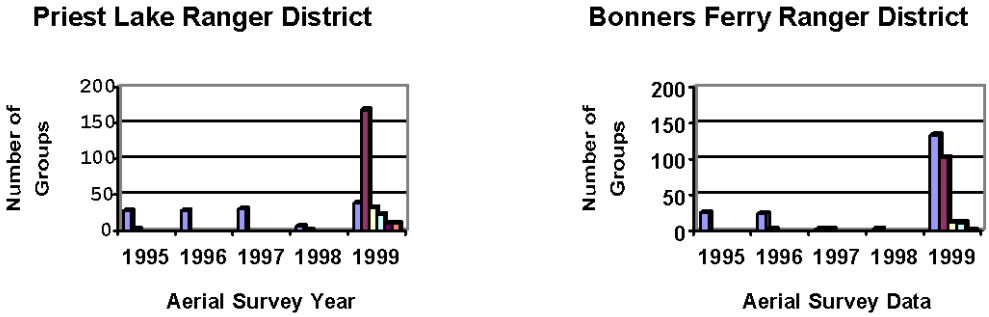




Ice storm damage was most dramatic on central Districts of the IPNFs, including Coeur d'Alene River and Sandpoint Ranger Districts. As in the southern Districts, ADS results in 1998 indicated that there was an increasing population of DFB on these Districts (numbers of DFB groups and average group sizes were larger in 1998 ADS than in 1997 ADS). With ice storms and heavy snow loads in the winter of 1996/1997, beetles emerging in the spring of 1997 had an abundance of preferred host material to colonize. The fact that green trees were killed also indicates that populations were high. In 1999, the two Ranger Districts in the central portion of the Forest had the most DFB groups mapped per District, and largest numbers of groups in the larger size classes (Figure 3, Appendix 1).

Northern Portion of the Forest: Priest Lake and Bonners Ferry

Figure 4. Numbers of Douglas-fir-beetle-killed groups of trees by approximate group size (numbers of faded trees) as mapped in aerial detection surveys for the Priest Lake and Bonners Ferry Ranger Districts of the IPNFs for aerial survey years 1995-1999.



The northernmost Ranger Districts' group distributions in 1998 and 1999 ADS were what would be expected if there were normal beetle populations before some large disturbance. In 1998, ADS for Priest Lake and Bonners Ferry beetle groups were practically non-existent whereas 20 to 30 groups were mapped for the Districts in 1995 and 1996. Though winter of 1995/1996 was unusually moist, either this did not translate into an abundance of down host material, or other factors prevented beetles from responding (in Bonners Ferry), numbers of DFB groups decreased in 1997 ADS indicating that beetles may have been infesting downfall. This did not occur on Priest Lake where 1997 ADS DFB group numbers were similar to those in 1995 and 1996 ADS. In 1997, endemic levels of beetles emerged from their hosts and preferentially attacked down material, killing few green trees compared to a more typical year. Beetle populations built up in down material, and in 1998 (1999 ADS) killed many green trees. Of the three regions, the northern Districts had fewest DFB groups mapped by Ranger District.

IPNFs Summary

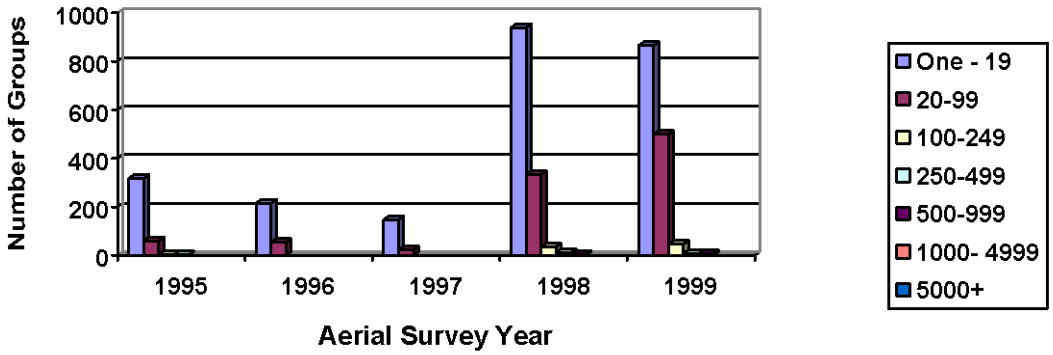
Polygon analysis indicates that beetle populations were increasing before the dramatic increase in mortality in 1998. When beetles have a choice, they will preferentially attack large-diameter, fresh windthrow over healthy green trees. If populations of beetles were at normal, endemic levels in 1996, before windthrow, there would have been little, if any, green tree mortality in 1997 as most beetles would have colonized the abundant windthrown and fresh, large-diameter slash (as witnessed on northern Districts). Aerial survey data in 1998 shows that Douglas-fir-beetle-caused mortality on the IPNFs increased in 1997 in spite of abundance of preferred host material. The combination of high beetle populations and abundant preferred breeding material in spring of 1997 and a shortage of downfall in winter of 1997/1998 resulted in beetles attacking green trees in 1998 as demonstrated by large numbers and sizes of DFB groups mapped in the 1999 aerial survey. Mortality was most prominent on central Districts where most damage from the winter of 1996/1997 occurred.

While beetles are capable of killing green trees, they are not as successful at reproducing in them and generating high populations to kill trees the next year. As a result, we predict that brood to parent ratio for beetles in the 1998 season will be significantly smaller than in 1997 or 1996 when beetles reproduced in defenseless down material. Winter of 1998/1999 was mild and the amount of fresh down DF available to beetles in spring of 1999 is not thought to have been above normal. We believe that because of reduced fecundity of beetles in 1998, fewer green DF were attacked in 1999 and DFB killed groups will decrease in total numbers and average sizes (numbers of dead trees) in 2000 ADS.

Clearwater National Forest

DFB caused mortality on the CNF increased in 1997 and 1998 (1998 and 1999 ADS). Winter precipitation was above average in 1995/1996 and likely created above average amounts of downed DF. In spring of 1996, emerging DFB had plentiful down material to colonize and fecundity rate increased. Though the CNF did not experience the storm in winter of 1996/1997, precipitation was above average and downfall was likely created. From aerial detection survey data, it is evident that DFB killed more green trees in 1997 than in 1996, but considerable green tree mortality continued into 1998. The sustained nature of beetle mortality indicates that though beetle populations attacked many green trees in 1997, a certain proportion of the population must have attacked down material enabling beetles to maintain a fecundity rate that would result in populations high enough to kill green trees into 1998. This trend was not evident on all Ranger Districts of the CNF.

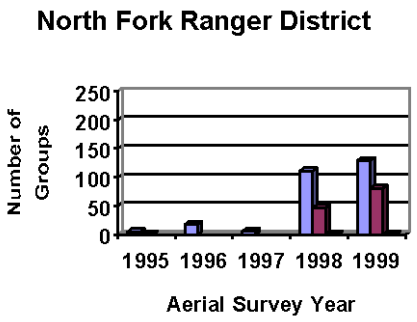
Figure 5. Numbers of Douglas-fir-beetle-killed groups of trees by approximate group size (numbers of dead trees) as mapped in aerial detection surveys for the Clearwater National Forest for aerial survey years 1995-1999.

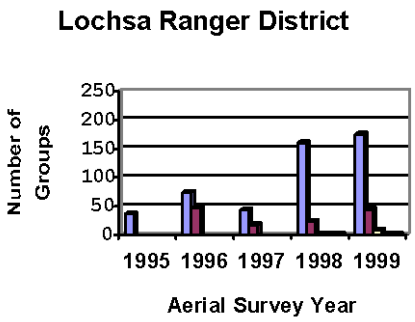


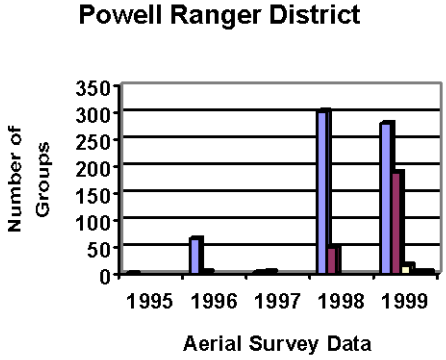
National Forest	Aerial Survey Year	Acres Infested	# Faded Trees
Clearwater NF	1995	6350	2174
	1996	607	2593
	1997	1367	2186
	1998	26734	25121
	1999	11659	34150

Three of five Ranger Districts on the CNF had an increase in the number of DFB groups mapped in 1999 over 1998 (1998 attacks/ 1997 attacks) (Figure 6).

Figure 6. Numbers of Douglas-fir-beetle-killed groups of trees by approximate group size (numbers of dead trees) as mapped in aerial detection surveys for Lochsa, Powell, and North Fork Ranger Districts of the Clearwater National Forest for aerial survey years 1995-1999.

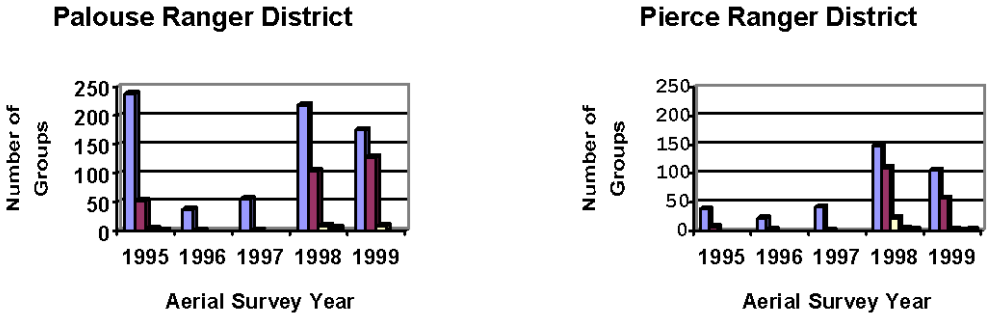






On the Palouse and Pierce Ranger Districts, numbers of DFB groups mapped declined in 1999 ADS from 1998 ADS (Figure 7, Appendix 2).

Figure 7. Numbers of Douglas-fir-beetle-killed groups of trees by approximate group size (numbers of dead trees) as mapped in aerial detection surveys for Palouse and Pierce Ranger Districts of the Clearwater National Forest for aerial survey years 1995-1999.

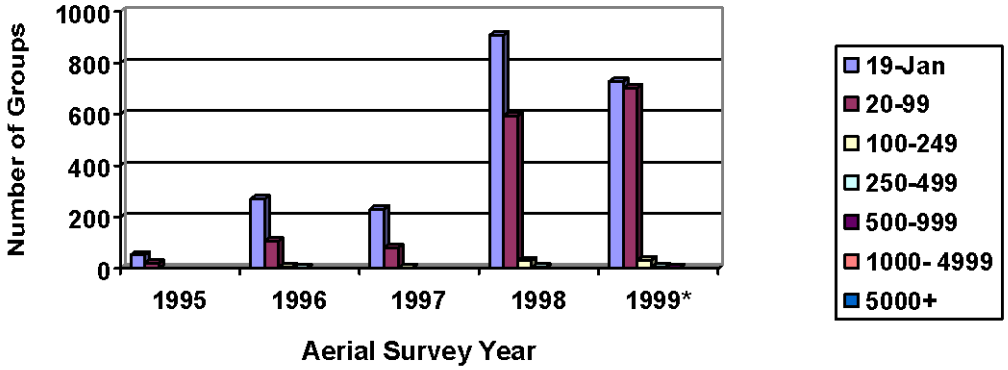


We feel the mild winters of 1997/1998 and 1998/1999 did not generate significant amounts of downfall. As a result, DFB fecundity rates have dropped and DFB-caused green tree mortality decreased on all Districts of the CNF in 1999. In 2000 ADS, all Districts are expected to have fewer DFB groups.

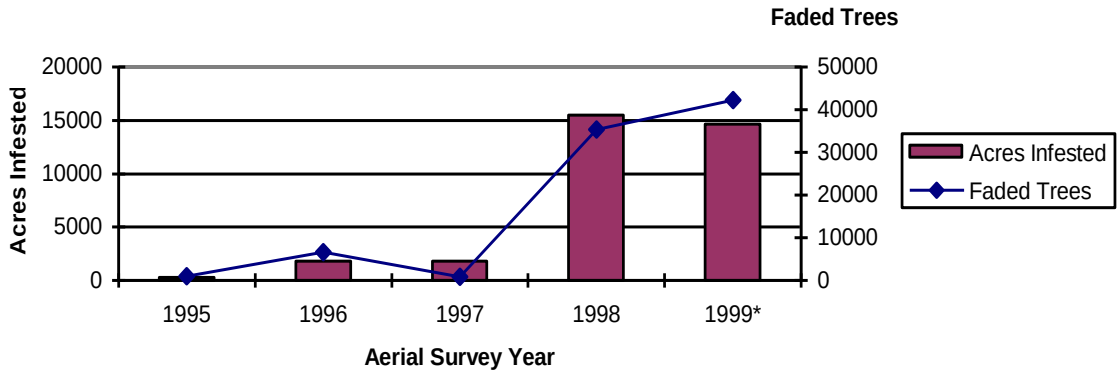
Nez Perce National Forest

Trees killed by DFB have been steadily increasing on the NPNF from 1994-1998 (1995-1999 ADS) (Figures 8, 9, 10, Appendix 3). In spite of an incomplete survey in 1999, the proportion of medium and larger groups to small groups indicate an increasing trend in beetle mortality from 1997 to 1998 (1998 ADS to 1999 ADS), a trend that would not have been apparent in acres infested and numbers of faded trees if ADS summaries only had been used.

Figure 8. Numbers of Douglas-fir-beetle-killed groups of trees by approximate group size (numbers of dead trees) as mapped in aerial detection surveys for the Nez Perce National Forest for aerial survey years 1995-1999. NOTE: 1999 ADS not complete.



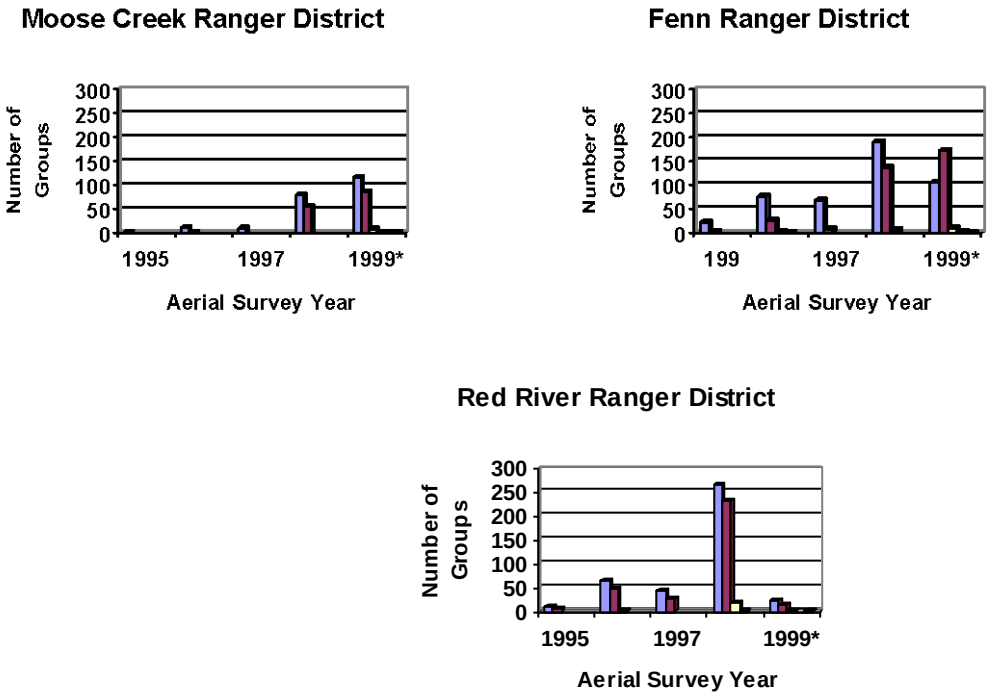
National Forest	Aerial Survey Year	Acres Infested	# Faded Trees
Nez Perce NF	1995	277	962
	1996	1,786	6,626
	1997	1,775	862
	1998	15,480	35,348
	1999	14,664	42,214



*1999 aerial surveys not complete for Fenn, Moose Creek, or Red River Ranger Districts.

In spite of incomplete ADS for Moose Creek, Fenn, and Red River Ranger Districts, data available indicates that mortality on Moose Creek and Fenn Ranger Districts continued to rise in 1998 over 1997. The majority of the Red River Ranger District was not flown so the sample was too small to make any conclusions (Figure 9, Appendix 3). In 1998 ADS, Red River Ranger District had most DFB groups mapped for the NPNF (514). It is probable that DFB activity on the Red River RD resulted in significant tree mortality in 1998 (1999 ADS).

Figure 9. Numbers of Douglas-fir-beetle-killed groups of trees by approximate group size (numbers of dead trees) as mapped in aerial detection surveys for Moose Creek, Fenn, and Red River Ranger Districts of the Nez Perce National Forest for aerial survey years 1995-1999. NOTE: 1999 ADS not complete.



Of the Districts with complete aerial survey data the largest increase in numbers of DFB groups mapped from 1998 ADS to 1999 ADS occurred on the Salmon River Ranger District (Figure 10, Appendix 3). In 1999 ADS, the number of medium-sized groups outnumbered the amount of small groups on this District.

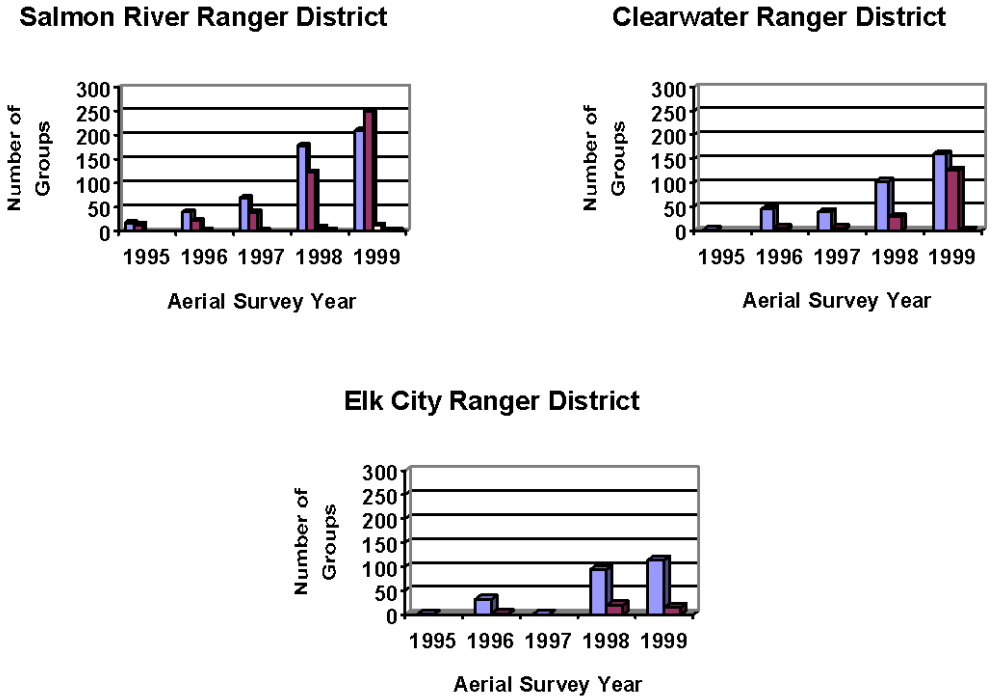
Douglas-fir beetle activity on the NPNF is unique. Group analysis data for individual Ranger Districts on the NPNF indicates that mortality has consistently increased from one year to the next for each of the past 5 years. Like the IPNFs and CNF, larger increases in mortality occurred in 1997 and 1998 (1998 and 1999 ADS); however, unlike those Forests, mortality also increased from 1994-1996 (1995-1997 ADS). With the group analysis, it is possible to say something about how the mortality appears across the landscape. On the Districts witnessing most beetle mortality, the proportion of medium-sized (20-99 faded tree) mortality groups increased, in some cases becoming more common than small (1-19 faded tree) mortality groups. It is not readily apparent why DFB mortality consistently increased on the NPNF. We anticipate that mortality in 1999 (2000 ADS) will be less than mortality in 1998 (1999ADS) based primarily on the mild winters of 1997/1998 and 1998/1999.

Conclusions

More information about the course of a DFB outbreak can be obtained by considering size (numbers of faded trees) and abundance of DFB groups across the landscape in addition to numbers of acres infested and numbers of faded trees traditionally reported. Group assessment allows for a more meaningful exploration of DFB trends in a particular area, emphasizes the group nature of DFB mortality, gives indications about distribution of beetles (1 5,000+ tree groups mapped vs. 1,000 5-tree groups), and it is more likely to yield information about beetle population trends in the absence of complete ADS.

Group analysis also provides managers with important information about distribution and size of mortality patches. Numbers of groups in each size class may be used by different resource specialists to determine impacts DFB mortality may have on resources and on treatment options. For example, larger groups may make salvage economical or regeneration harvests feasible if groups are very large. Mortality levels of 1 or 2 trees per acre may impact few resources, but concentrated mortality that creates significant openings in canopies may impact many resources.

Figure 10. Numbers of Douglas-fir-beetle-killed groups of trees by approximate group size (numbers of dead trees) as mapped in aerial detection surveys for Salmon River, Clearwater, and Elk City Ranger Districts of the Nez Perce National Forest for aerial survey years 1995-1999.



Though ADS information is not as precise as ground survey information, and because it is always one year old, it is better suited to yielding information on the way that DFB acts across a landscape. Aerial detection surveys also provide more cost-effective coverage than current ground survey methods, and can be completed in a more timely fashion. Ground survey data will compliment ADS information.

Literature Cited

Furniss, M.M., M.D. McGregor, M.W. Foiles, and A.D. Partridge. 1979. Chronology and characteristics of a Douglas-fir beetle outbreak in northern Idaho. USDA Forest Service, General Technical Report INT-59.

Appendix

Appendix 1. Numbers of Douglas-fir-beetle-killed groups of trees by rough group size (numbers of dead trees) as mapped in aerial detection surveys for Ranger Districts on the Idaho Panhandle National Forests for aerial survey years 1995-1999.

Ranger Districts	Aerial Survey Year	Numbers of Faded Trees						
		1-19	20-99	100-249	250-499	500-999	1000-4999/5000	TOTAL
Avery	1995	0						0
	1996	44						44
	1997	4						4
	1998	100	45					145
	1999	174	277	10				461
St. Maries	1995	77	6					83
	1996	5						5
	1997	1						1
	1998	73	17					90
	1999	127	164	10	3			304
Fernan	1995	22						22
	1996	10						10
	1997	17						17
	1998	47	1					48
	1999	189	306	23	3	3		524
Wallace	1995	5						5
	1996	4						4
	1997	3						3
	1998	27	5					32
	1999	232	648	73	14	8	0/1	976
Sandpoint	1995	35	2					37
	1996	37	1					38
	1997	17	0					17
	1998	68	13					81
	1999	206	346	29	11	3		595
Priest Lake	1995	28	2					30
	1996	28						28
	1997	30						30
	1998	6	1					7
	1999	38	168	32	23	11	10	282
Bonners Ferry	1995	25						25
	1996	24	2					26
	1997	2	2					4
	1998	2						2
	1999	133	102	12	11	1		259

Appendix 2. Numbers of Douglas-fir-beetle-killed groups of trees by rough group size (numbers of dead trees) as mapped in aerial detection surveys for Ranger Districts on the Clearwater National Forest for aerial survey years 1995-1999.

Ranger Districts	Aerial Survey Year	Numbers of Faded Trees						
		1-19	20-99	100-249	250-499	500-999	1000-4999	TOTAL
Lochsa	1995	36						36
	1996	74	46					130
	1997	43	17					60
	1998	160	23	1	1	1		186
	1999	175	44	8	1	1		229
Powell	1995	0						0
	1996	65	4					69
	1997	2	3					5
	1998	302	50					352
	1999	280	189	15	4	3		491
Pierce	1995	38	7					45
	1996	22	2					24
	1997	41	1					42
	1998	148	110	22	4	2		286
	1999	106	57	3	1	2		169
North Fork	1995	5	1					6
	1996	18						18
	1997	6						6
	1998	111	47	1				159
	1999	129	81	1				211
Palouse	1995	238	52	3	1			294
	1996	37	1					38
	1997	55	1					56
	1998	218	104	9	5			336
	1999	175	128	8				311

Appendix 3. Numbers of Douglas-fir-beetle-killed groups of trees by rough group size (numbers of dead trees) as mapped in aerial detection surveys for Ranger Districts on the Nez Perce National Forest for aerial survey years 1995-1999.

Ranger Districts	Aerial Survey Year	Number of Faded Trees						
		1-19	20-99	100-249	250-499	500-999	1000-4999	TOTAL
Salmon River	1995	17	13					30
	1996	40	22	2				64
	1997	69	39	1				109
	1998	178	123	7	2			310
	1999	210	250	12	2	1		475
Red River	1995	11	5					16
	1996	66	49	1				116
	1997	45	28					37
	1998	264	231	17	2			514
	1999*	21	15	1	0	1		38
Elk City	1995	1						1
	1996	32	2					34
	1997	0						0
	1998	94	20					114
	1999	114	15					129
Clearwater	1995	2						2
	1996	45	6					51
	1997	39	6					45
	1998	103	29					132
	1999	160	126	1				287
Fenn	1995	22	3					25
	1996	76	26	2	1			105
	1997	68	8					76
	1998	190	136	6				332
	1999*	105	172	10	3	1		291
Moose Creek	1995	0						0
	1996	11	1					12
	1997	10						10
	1998	79	55					134
	1999*	116	86	8	0	0	1	211

*In 1999 Aerial surveys were not flown over the majority of the Red River Ranger District, and significant portions of the Fenn and Moose Creek Ranger Districts of the Nez Perce National Forest. 1998 aerial survey mapped significant Douglas-fir beetle mortality in these areas and it is likely that additional mortality would have been mapped in 1999.